***********************DRAFT*************************

SYNOPSIS V1.0:

Heavy Ion Transient and Latch-up Test Results for the Analog Devices OP42 Operational Amplifier

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I. INTRODUCTION

This study was undertaken to determine the Single Event Transient (SET) and Single Event Latch-up (SEL) sensitivity of the Analog Devices OP42 Operational Amplifier.

II. DEVICES TESTED

Two Device Under Test (DUT) samples of the Analog Devices OP42 Operational Amplifier were tested. Lot Date Code for the parts tested is 9750.

DUT 1 Package Markings: AD 5962-8851301PA Q
7D9750B

DUT 2 Package Markings: AD 5962-8851301PA Q
7D9750B

III. TEST FACILITY

Facility: Texas A&M University Single Event Upset Test Facility.
Flux Range: 5.19×10^2 to 2.12×10^5 particles/cm^2/s.
Particles: Neon, Argon, Krypton, and Xenon ions were used.

Ion	Energy (MeV)	LET (MeVcm^2/mg)
Ne	264	2.64
Ar	496	8.05
Kr	942	28.90
Xe	1722	49.30

IV. TEST METHODS

Temperature: room temperature

Test Hardware: A custom test set was used to supply nominal input levels to the DUTs and monitor the bias supply current for changes resulting from the radiation exposure. Files were generated for each DUT to track changes in the supply current with a measurement accuracy 100 pA. The current was measured and recorded at 10 ms intervals throughout the exposure. A digital oscilloscope was used to monitor the output of the DUT for transient events during the irradiation.

Software: Customized LABVIEW® software provided a user interface to control signals to the DUT. The software also automatically monitored supply currents and generated a file history. The software automatically turned off the DUT power supply when the current exceeded a user-defined value. This predefined current is called the limiting current (I_L). The software also records all transient events to an output file seen by the digital oscilloscope.

Test Techniques: Tests were performed to screen for the possibility of transients and latch-up and measure sensitivity as a function of particle LET for an application specific test setup. Test conditions included the operational amplifier configured as a voltage follower with V_+ = 0.4 Volts Peak-to-Peak and V_- tied to the output with the supply voltage set to $V_{cc} = \pm$ 6.5 Volts. A fluence of 1×10^7 ions/cm^2 or less was used at each test condition. The effects observed determined the fluence used. If no transients or latchup events occurred, the fluence was run to at least 1×10^7 ions/cm^2. If the desired number of transients were observed prior to reaching 1×10^7 ions/cm^2 the beam was stopped and the fluence recorded. The beam flux range of 5.19×10^2 to 2.12×10^5 particles/cm^2/s resulted in individual exposures of about between 47 seconds and 8 minutes.

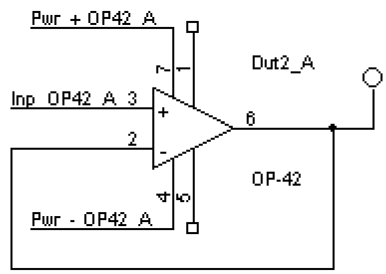


Figure 1. OP42 Operational Amplifier configured as a voltage follower.

The input voltage condition was evaluated at 12 different values of Effective Linear Energy Transfer (LET). Testing began with a normal incident LET of 2.64 MeV-cm^2/mg obtained with Neon ions, followed with a normal incident LET of 8.05 MeV-cm^2/mg obtained with Argon ions, then a normal incident LET of 28.90 MeV-cm^2/mg obtained with Krypton ions, and finally a normal incident LET of 49.30 MeV-cm^2/mg obtained with Xenon ions. Angles of 30, 45 and 60 degrees were used to achieve the additional values of effective LET. Two samples were tested under all voltage conditions.

If the device current experienced a sudden increased larger than I_L, the power was cycled and the DUT was checked for functionality, we called this an SEL. The DUT functionality information was not saved to a file. Any transient events observed by the digital oscilloscope were recorded and saved to a file.

V. RESULTS

The devices were exposed from a fluence of 5.89×10^4 to 1×10^7 particles/cm^2 of the Neon, Argon, Krypton, and Xenon ions with no single event latchups. The Analog Devices OP42 is considered to have an LET threshold for latchup greater than 57.8 MeV-cm^2/mg.

The test conditions and results are summarized in Table 1. The table is organized such that the input conditions and angle of incidence are sorted by increasing LET. A quick look at the results shows that for an LET of 2.64, a small number of transients were observed at 0 degrees. As the angle and LET were increased, more transients were observed.

Table 1. Test Conditions & Results

DUT #	Angle (Degrees)	V_{cc} (Volts)	V_+ (Volts)	Output (Volts)	Effective LET (MeV-cm^2/mg)	Number of Transients	Cross Section (cm^2)
2	0	6.5	0.4	0.4	2.64	2	2.01E-07
2	0	6.5	0.4	0.4	2.64	4	3.96E-07
1	0	6.5	0.4	0.4	2.80	5	5.00E-07
1	0	6.5	0.4	0.4	2.80	4	4.02E-07
2	0	6.5	0.4	0.4	2.80	3	3.01E-07
2	0	6.5	0.4	0.4	2.80	8	8.00E-07
1	30	6.5	0.4	0.4	3.23	6	6.00E-07
1	30	6.5	0.4	0.4	3.23	15	1.50E-06
2	30	6.5	0.4	0.4	3.23	18	1.80E-06
2	30	6.5	0.4	0.4	3.23	28	2.81E-06
1	45	6.5	0.4	0.4	3.96	52	5.20E-06
1	45	6.5	0.4	0.4	3.96	49	4.90E-06
2	45	6.5	0.4	0.4	3.96	48	4.80E-06
2	45	6.5	0.4	0.4	3.96	54	5.40E-06
1	60	6.5	0.4	0.4	5.60	103	2.65E-05
1	60	6.5	0.4	0.4	5.60	217	2.87E-05
2	60	6.5	0.4	0.4	5.60	404	6.41E-05
2	60	6.5	0.4	0.4	5.60	240	7.00E-05
2	0	6.5	0.4	0.4	8.69	6	6.01E-07
1	0	6.5	0.4	0.4	8.69	808	6.68E-04
1	0	6.5	0.4	0.4	8.69	354	7.73E-04
2	0	6.5	0.4	0.4	8.69	268	9.24E-04
2	0	6.5	0.4	0.4	8.69	348	8.06E-04
1	30	6.5	0.4	0.4	10.03	296	1.16E-03
1	30	6.5	0.4	0.4	10.03	312	1.24E-03
2	30	6.5	0.4	0.4	10.03	329	1.48E-03
2	30	6.5	0.4	0.4	10.03	345	1.52E-03
1	45	6.5	0.4	0.4	12.29	306	1.57E-03
1	45	6.5	0.4	0.4	12.29	295	1.55E-03
2	45	6.5	0.4	0.4	12.29	330	1.79E-03

2	45	6.5	0.4	0.4	12.29	340	1.79E-03
1	60	6.5	0.4	0.4	17.38	318	2.67E-03
1	60	6.5	0.4	0.4	17.38	345	2.80E-03
2	60	6.5	0.4	0.4	17.38	339	2.61E-03
2	60	6.5	0.4	0.4	17.38	354	2.95E-03
2	0	6.5	0.4	0.4	28.90	1263	3.33E-03
2	0	6.5	0.4	0.4	28.90	404	3.88E-03
1	0	6.5	0.4	0.4	28.90	238	2.44E-03
1	0	6.5	0.4	0.4	28.90	286	2.55E-03
2	30	6.5	0.4	0.4	33.37	317	3.76E-03
2	30	6.5	0.4	0.4	33.37	323	3.87E-03
1	30	6.5	0.4	0.4	33.37	262	2.99E-03
1	30	6.5	0.4	0.4	33.37	239	2.68E-03
2	45	6.5	0.4	0.4	40.87	279	3.43E-03
2	45	6.5	0.4	0.4	40.87	264	3.10E-03
1	45	6.5	0.4	0.4	40.87	254	3.42E-03
1	45	6.5	0.4	0.4	40.87	235	3.01E-03
1	0	6.5	0.4	0.4	49.30	148	1.48E-05
2	0	6.5	0.4	0.4	49.30	142	1.42E-05
2	60	6.5	0.4	0.4	57.80	261	3.92E-03
2	60	6.5	0.4	0.4	57.80	261	4.10E-03
1	60	6.5	0.4	0.4	57.80	309	4.05E-03
1	60	6.5	0.4	0.4	57.80	221	3.75E-03

Next conside4ring the single event transients, Figure 2 shows the SET cross section as a function of the effective LET. A Weibul fit of the data shows an approximate LET threshold of 3 MeV-cm^2/mg and a saturation cross-section of approximately 6 x 10^{-3} cm^2. Figures 3 – 6 show sample transients (each figure containing a best and worst case transient) for LETs of 2.8, 17.4, 28.9, and 57.8MeV-cm^2/mg, respectively. Worst case transients appear to go from –1 to +1 volts and have widths in the few microsecond regime.

In summary, the OP42 is considered to have an LET threshold for latchup greater than 57.8 MeV-cm^2/mg. For single event transients, the approximate LET threshold is 3 MeV-cm^2/mg and the device saturation is about 6 x 10^{-3} cm^2. It must be noted that these results are for the application specific test condition as requested by the MLA project and are therefore only applicable to those conditions.

VI. COMMENTS AND RECOMMENDATIONS

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1 Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2 Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3 Recommended for usage in some NASA/GSFC spaceflight applications but requires extensive mitigation techniques or hard failure recovery mode.
Category 4 Not recommended for usage in any NASA/GSFC spaceflight applications.

The Analog Devices OP42 Operational Amplifiers are considered category 2 devices.

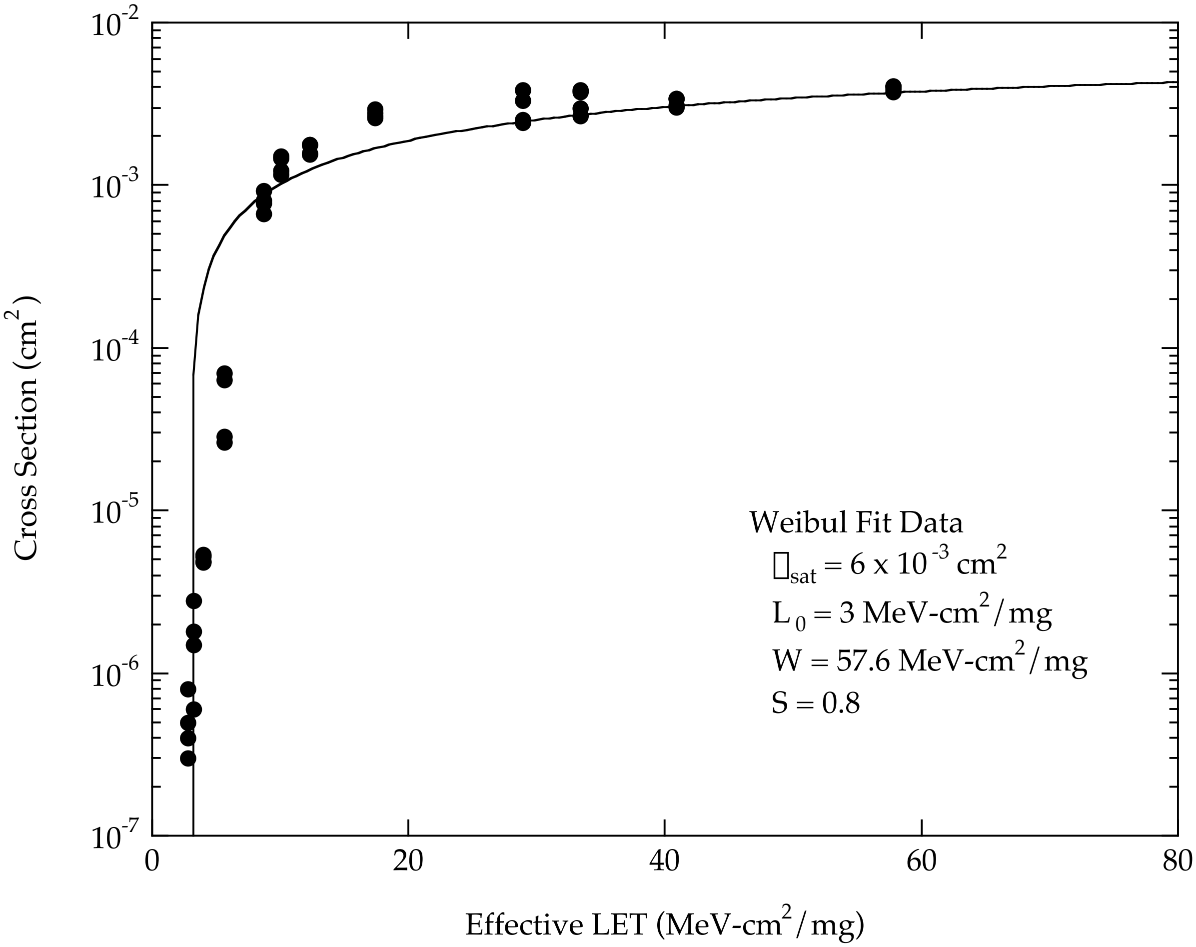


Figure 2. Cross Section versus Effective LET for Operational Amplifier configured as a voltage follower. The Weibul fit parameters are shown in the figure giving an approximately LET threshold of 3 MeV-cm^2/mg and saturation cross-section of approximately 6 x 10^{-3} cm^2.

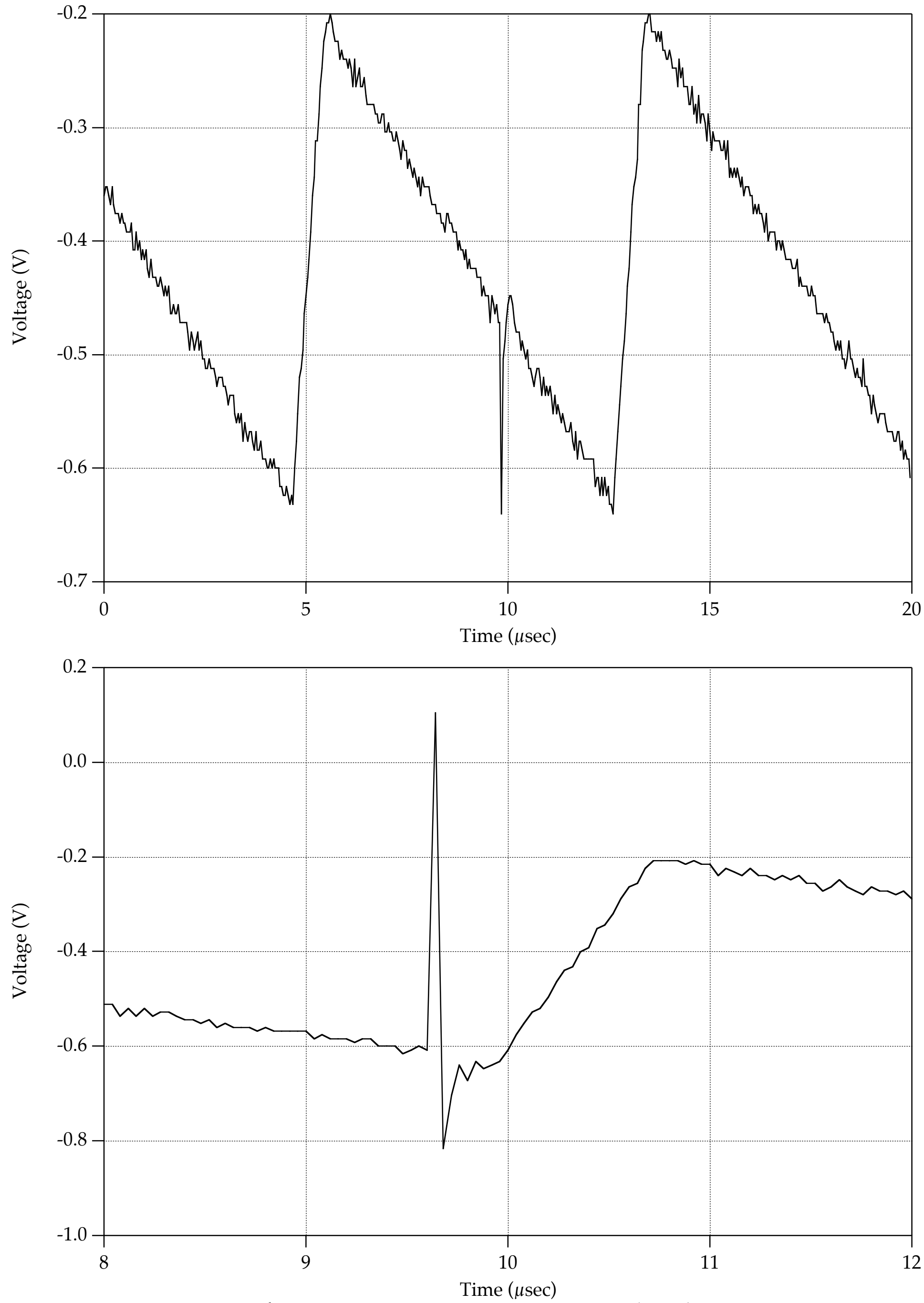
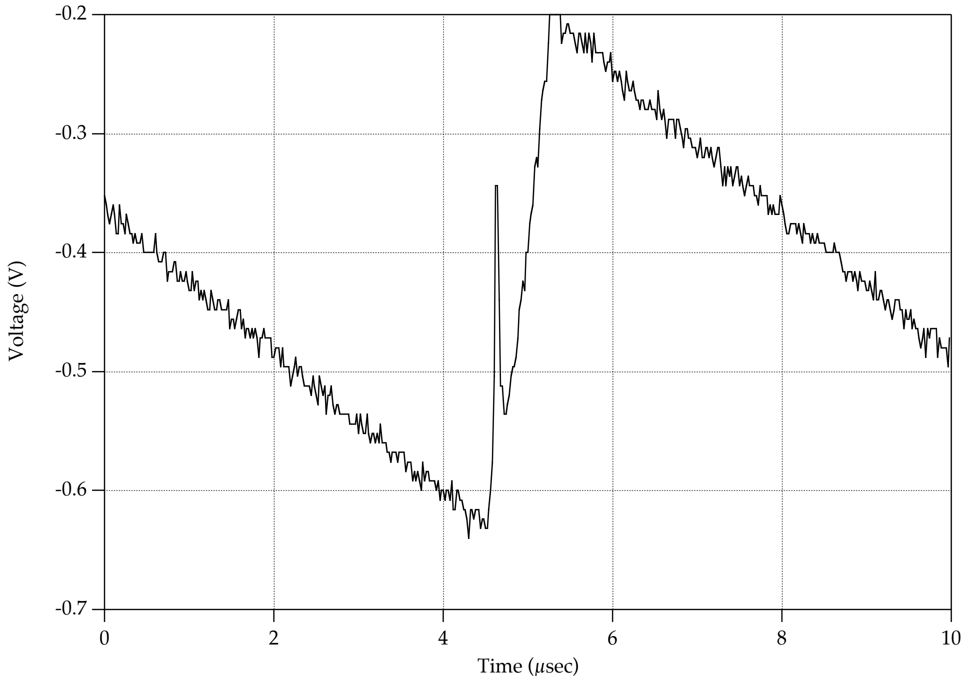


Figure 3. Sample transients showing a simple transient (top) and a worst-case transient (bottom) for an LET of 2.8 MeV-cm^2/mg.



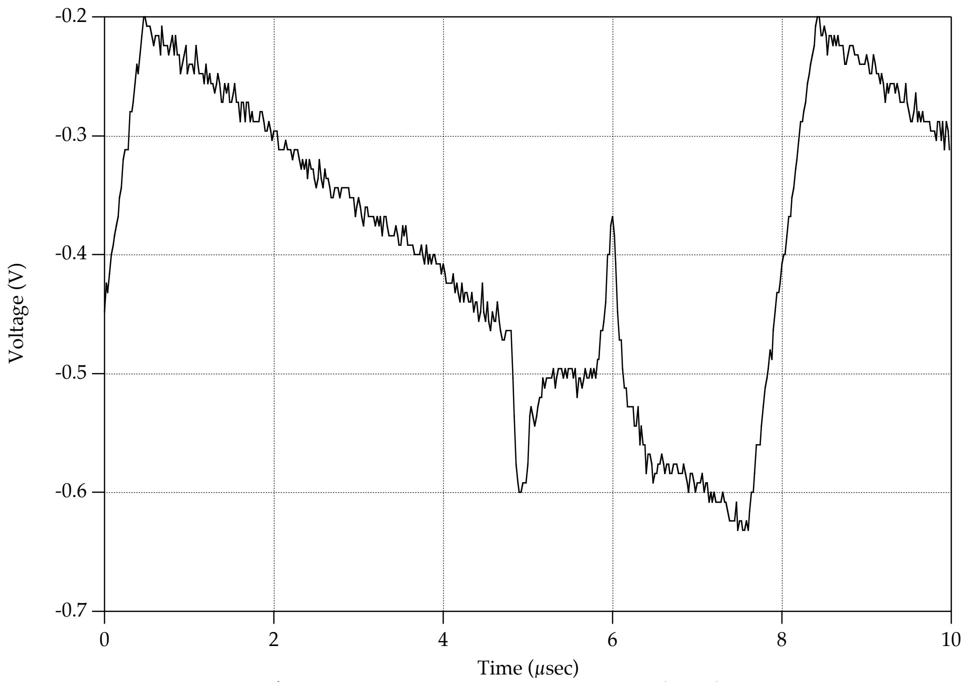
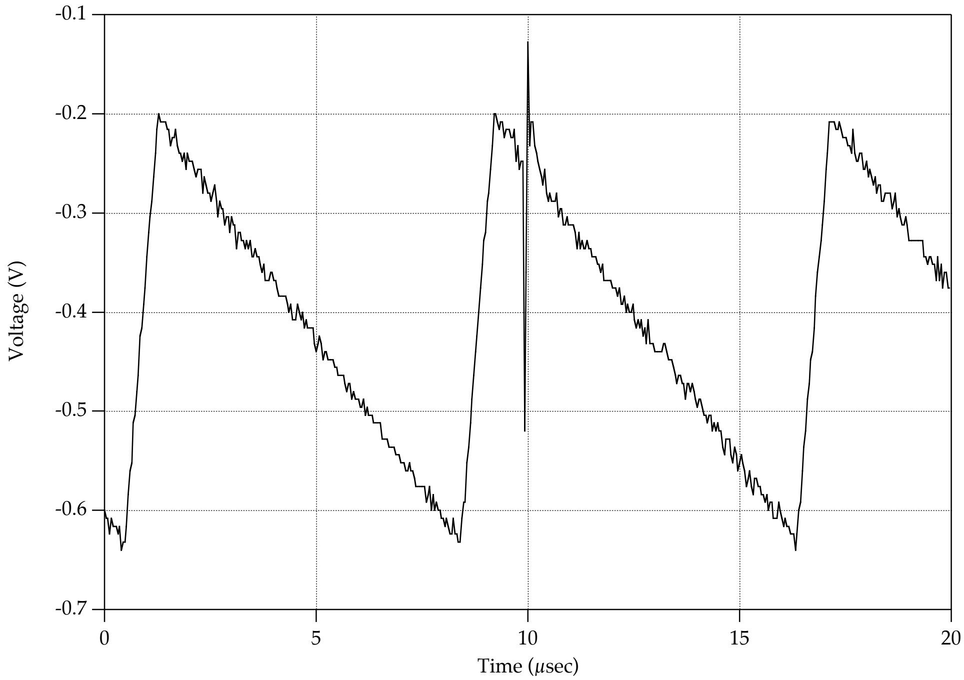


Figure 4. Sample transients showing a simple transient (top) and a worst-case transient (bottom) for an LET of 17.4 MeV-cm^2/mg.



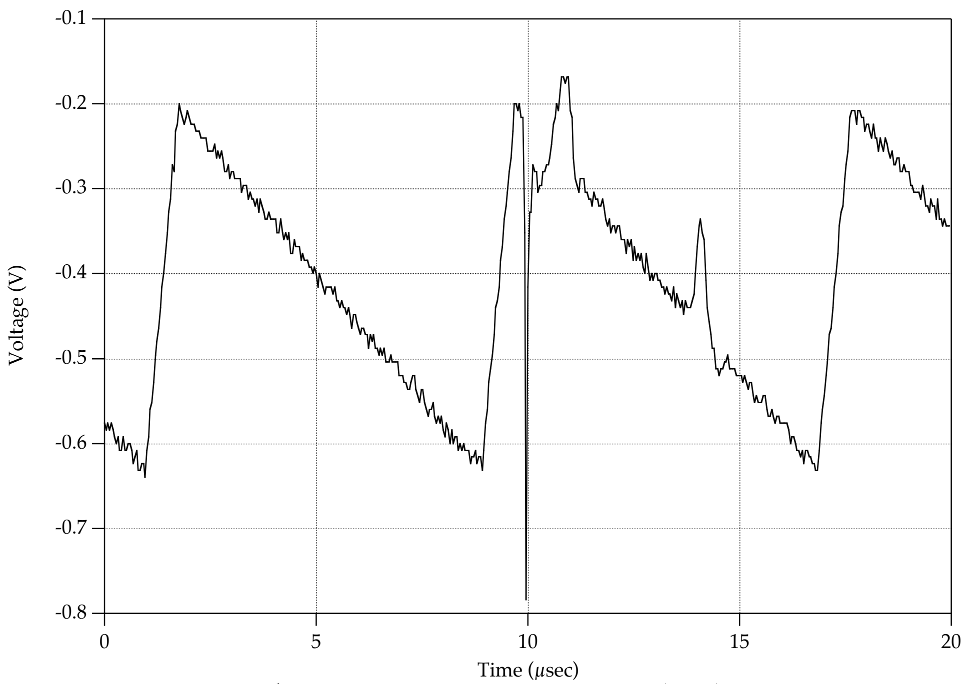


Figure 5. Sample transients showing a simple transient (top) and a worst-case transient (bottom) for an LET of 28.9 MeV-cm^2/mg.

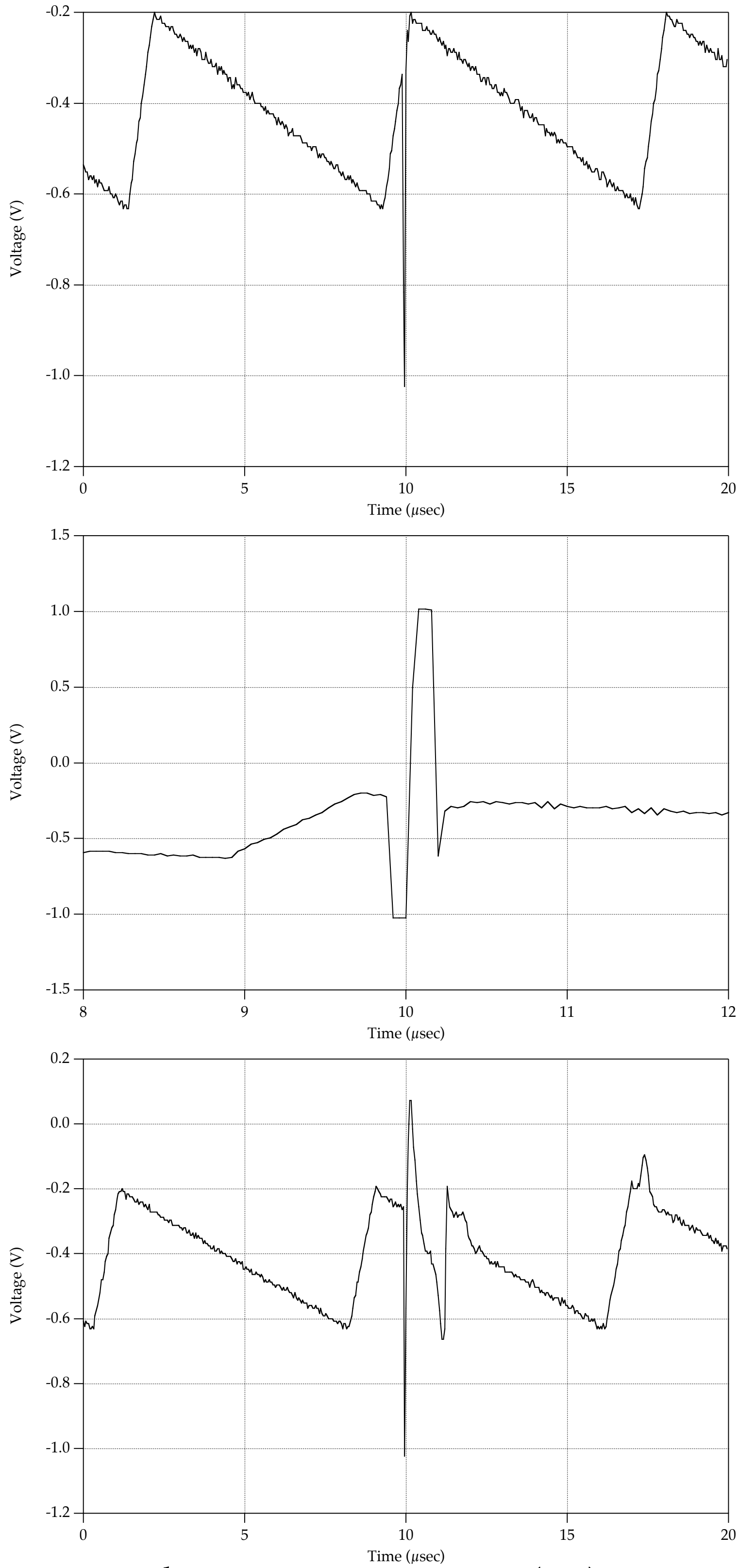


Figure 6. Sample transients showing a simple transient (top) and a worst-case transients (middle and bottom) for an LET of 57.8 MeV-cm^2/mg.